Laboratory Simulation Studies on Evaporative Fuel Loss from Storage Tanks

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Abstract. The fossil fuel is used for various activities; however, it is available in limited quantity and burning of fossil fuel causes global warming. The fuel loss from fuel tanks causes volatile organic emission. When two-wheeler is parked in hot sun during summer, there is evaporation loss of fuel from the fuel tanks. In this work, experimental work was carried out in laboratory, to understand fuel losses at various temperature such as 35, 40 and 45 degree C. From this work, it was observed that the air temperature significantly affects the fuel loss. The fuel loss increases with increase in air temperature and higher evaporation losses were observed at 45-degree C. To simulate the fuel storage tank with different level of fuel in the tank, experiments were conducted with beakers of different capacity such as 80, 100 and 200 mL which has the surface area of 101, 149 and 226 cm^2. From the experiments, it was observed that the fuel evaporation loss increases with increase in surface area of the beaker. The surface is of 226 cm^2 causes highest fuel evaporation loss as compared to other surface areas. From this work, we suggest that evaporative losses be minimized through appropriate mitigation measures.

1. Introduction

The long-term availability of affordable, accessible, and environmentally friendly energy sources is crucial for the economic growth of any country, as energy serves as a driving force for the economy. With global energy demand on the rise, the need for affordable and reliable energy will continue to be a key factor shaping future energy consumption trends [1]. The global demand for fossil fuels has been steadily increasing due to population growth, industrialization, and expanding energy needs. Current assessments suggest that existing oil reserves, combined with ongoing exploration and technological advancements in extraction methods, will be sufficient to meet this rising demand until at least 2030. [2]. The rapid phase-out of fossil fuel production is a big concern for the real economy and financial markets. This will require the write-down of significant, operational capital assets and reserves that are

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represented as assets on the balance sheets of fossil energy corporations [3]. Addressing climate change necessitates a swift and significant reduction in the use of fossil fuels. At COP26 in November 2021, two notable declarations such as statement international public support for the clean energy transition and just transition declaration, were introduced to accelerate this effort [4]. The human health hazards and climate change are linked to anthropogenic greenhouse gases and aerosols. It is proposed that a large reduction in the excess mortality rate is possible. Approximately 70% of the anthropogenic aerosol-induced climate cooling and 65% of excess mortality worldwide are caused by emissions from fossil fuels. According to studies, 61% of all deaths connected to exposure to fine particulate matter and ground-level ozone are caused by fossil fuels. Depending on variables including energy consumption, industrial operations, and air quality management measures in various parts of the world, the percentage of deaths linked to fossil fuels that result in overall air pollution-related mortality varies greatly by location [5].

The VOCs are organic compounds with high vapour pressures that can escape from liquids as gases. They come from a wide range of sources, and anthropogenic VOCs are released from many man-made sources such as evaporation of organic solvents etc [6]. The VOCs are significant air pollutants in urban environments and have been increasingly drawing global attention. The VOCs pose serious health risks, contributing to respiratory illnesses and, in some cases, exhibiting mutagenic or reproductive toxicity, potentially harming unborn children [7]. The five identified sources of VOCs demonstrated distinct diurnal patterns, influenced by their varying emission characteristics and the effects of meteorological conditions [8]. The mobile sources, including vehicles such as cars, trucks, buses, and motorcycles, have historically been the largest contributors to VOC emissions in urban areas and this dominance stems from several factors [9].

2. Literature Review

The evaporative losses account for about half of the operating losses related to gasoline tanks. The evaporation losses and losses resulting from modifications in fluid composition are the two primary categories into which these losses can be generally divided. The evaporation losses happen when fuel's volatile ingredients leak into the atmosphere as a result of heat exposure, changes in pressure, or inadequate storage tank sealing. The chemical and physical changes inside the stored fuel cause losses resulting from changes in fluid composition. When liquid hydrocarbons are stored, temperature changes cause significant losses. Some estimates place the amount of oil lost during storage and transit before it reaches customers at at least 5%, or about 25 million tons per year. Approximately a quarter of these losses, or 6.25 million tons, can be ascribed to variations in storage temperature. According to research, a number of variables, such as the temperature of the surrounding air, the length of the trip, the speed of the vehicle, and the volume of fuel in the tank, can have a substantial impact on fuel losses. Changes in the evaporation rate and thermal dynamics are influenced by each of these factors. Furthermore, fuel losses are made worse by the combination of lengthy travel times and fast vehicle speeds. These circumstances cause a substantial buildup of heat in the fuel tank, raising the gasoline's temperature and quickening evaporation [10].

Four forms of heat losses—radiation, convection, conduction, and heat storage of the hot gases—as well as the temperature inside the fuel storage compartment were monitored and quantified in a study. These measurements were made at different compartment scales, opening sizes, and heat release rates [11]. Fuel losses can be calculated using a variety of direct and indirect approaches. One study used a methodology that compared the characteristics of crude oil and its derivatives. This method sought to estimate the losses in the quantities kept at a dispatch warehouse by analyzing the characteristics of two particular

products, gas oil and kerosene [12].
Because they are more volatile, lighter petroleum fractions have a tendency to evaporate while being stored. Evaporation rates continue to be substantial, particularly in specific climatic situations, despite the development of technologies such as floating roofs to mitigate these losses. According to reports, losses from unleaded gasoline tanks frequently above allowable thresholds. Because they are more volatile, lighter petroleum fractions have a tendency to evaporate while being stored. Evaporation rates continue to be substantial, particularly in specific climatic situations, despite the development of technologies such as floating roofs to mitigate these losses. According to reports, losses from unleaded gasoline tanks frequently above allowable thresholds [13].

3. Materials and methodology

In this work, evaporative fuel losses from fuel tanks with different level of fuel in the fuel tank was simulated by using glass beakers of different capacity such as 80, 100 and 200 mL. The surface area of the beakers of capacity 80, 100 and 200 mL are 101, 149 and 226 cm^2 respectively. The beakers containing the petrol was heated uniformly using the water bath and the temperature considered in this work are 35, 40 and 45 degree C. This is because, in summer the fuel tank temperature may increase due to higher solar radiation and higher ambient temperature. A digital weighing machine was used for weighing the evaporation loss.

4. Experimental setup and procedure

The beakers of capacity 80, 100 and 200 mL were cleaned with acetone to remove the impurities. Then these beakers again washed with small quantity of petrol to remove the traces of acetone from the beakers. After drying, the beakers were filled with petrol of their respective capacities such as 80, 100 and 200 mL. The water bath consists of a steel vessel containing water is heated to 35 degree C. After the water bath temperature reached, 35 degree C, all the beakers were placed in the vessel such that the level of water in the water bath is slightly higher than the level of petrol in the beakers. After every 10 min, the beakers were taken out from the water bath and the weight was measured. The difference in weight of the beakers before and after the 10 min, gives the rate of evaporation of petrol from the beakers. Similar procedure was followed for 20, 30, 40, 50 and 60 min. Figure 1 shows the experimental setup and weighing scale used in this work. A digital thermocouple was used to measure the ambient temperature and the experiments were conducted during February 2024 at Bangalore, India.

Fig. 1. Experimental Setup

5. Results and discussion

The evaporation loss studies in the laboratory scaled was conducted successfully and the results are discussed below. Figure 2 shows the evaporation loss from beakers of capacity 80, 100 and 200 cm^2 and at the water bath temperature of 35 degree C. From the figure it is observed that the evaporation loss increases with time and reaches maximum value at 60 min. The petrol contains the volatile materials and hence the evaporation losses increases with time. This figure also shows the effect of different surface areas of the beakers on the evaporation loss. It is observed from the figure that the evaporation fuel loss from the 80 ml beaker having a surface area of 101 cm^2. As the surface area increases, the evaporation losses also increase gradually. The highest evaporation loss was observed with the surface area of 226 cm^2. It shows that the effect of fuel which is exposed to different level of petrol in the tank. The results suggest that the surface is of the tank or level of fuel in the tank should not have longer surface areas as it may cause higher evaporative loss.

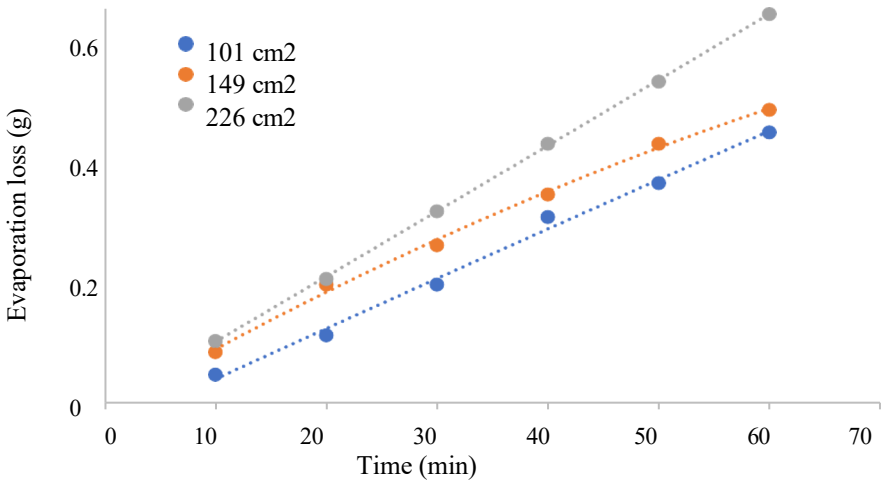

Fig. 2. Evaporation loss at 35 degree C with different beakers.

Figure 2 depicts the evaporation loss from beakers of capacity 80, 100 and 200 cm^2 and at the water bath temperature of 40 degree C. From the figure it is observed that the evaporation loss increases with time and reaches maximum value at 60 min and this trend is similar to similar type of observations recorded at 35 degree C. This figure also shows the effect of different surface areas of the beakers on the evaporation loss. It is observed from the figure that the evaporation fuel loss from the 80 ml beaker having a surface area of 101 cm^2. As the surface area increases, the evaporation losses also increase gradually. The highest evaporation loss was observed with the surface area of 226 cm^2. This results also similar to similar types of observations recorded at 35 degree C.

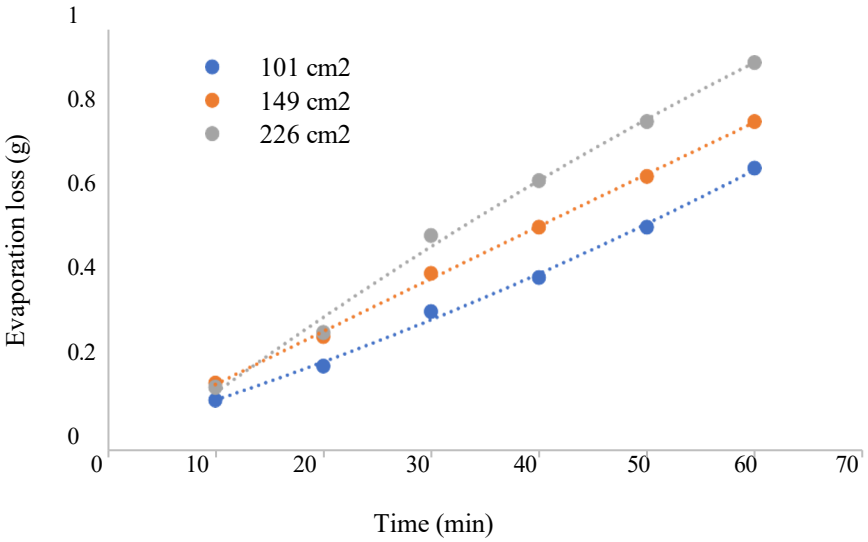

Fig. 3. Evaporation loss at 40 degree C with different beakers.

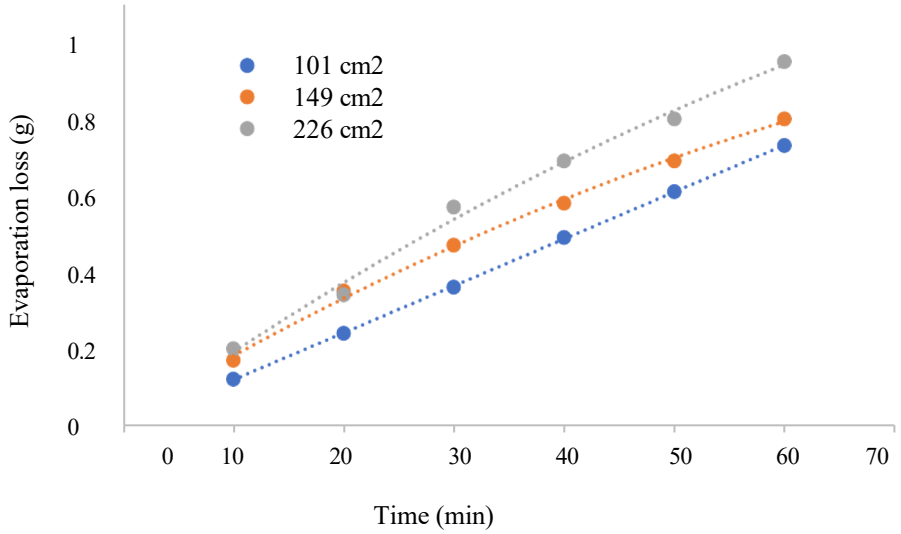

Fig. 4. Evaporation loss at 40 degree C with different beakers.

Figure 4 depicts the evaporation loss from beakers of capacity 80, 100 and 200 cm^2 and at the water bath temperature of 45 degree C. From the figure it is observed that the evaporation loss increases with time and reaches maximum value at 60 min and this trend is similar to similar type of observations recorded at 35 degree C. This figure also shows the effect of different surface areas of the beakers on the evaporation loss. It is observed from the figure that the evaporation fuel loss from the 80 ml beaker having a surface area of 101 cm2. As the surface area increases, the evaporation losses also increase gradually. The highest evaporation loss was observed with the surface area of 226 cm^2. This results also similar to similar types of observations recorded at 45 degree C.

Figure 5 compares the fuel losses from the beaker of capacity 80 mL ai different temperatures such as 35, 40 and 45 degree C. From this figure, it is observed that the evaporation loss of petrol from the beaker increases with time. Since the petrol is volatile fuel, the evaporation loss increases with increase in time. Also, the evaporation loss increases with increase in temperature of the petrol. The petrol temperature of 35 degree C causes lower evaporation fuel loss, however the evaporation loss increases with increase in temperature to 40 degree C. The highest evaporative fuel loss from 80 mL beaker was observed with 45 degree C.

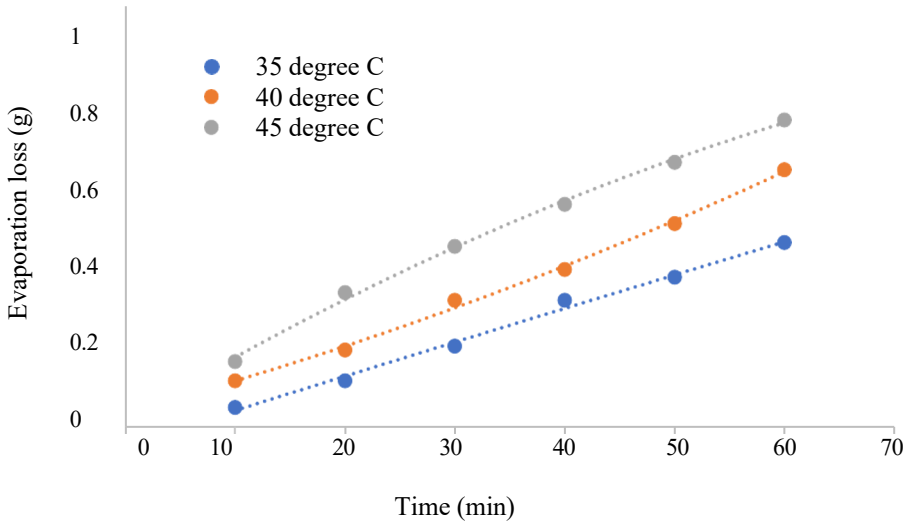

Fig 5. Evaporation loss from 80 mL beaker at different temperatures.

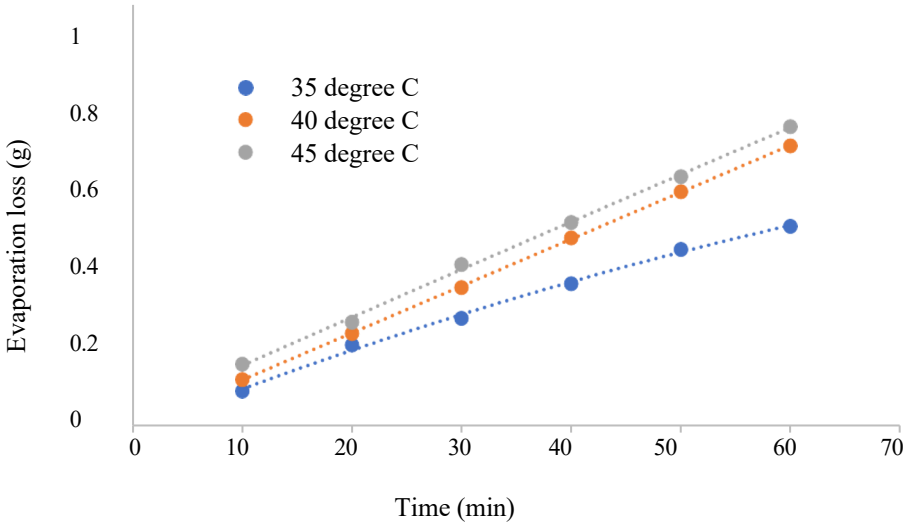

Fig. 6. Evaporation loss from 100 mL beaker at different temperatures.

Figure 6 compares the fuel losses from the beaker of capacity 100 mL ai different temperatures such as 35, 40 and 45 degree C. From this figure, it is observed that the evaporation loss of petrol from the beaker increases with time and this trend is similar to figure 5. Since the petrol is volatile fuel, the evaporation loss increases with increase in time. Also, the evaporation loss increases with increase in temperature of the petrol. The petrol temperature of 35 degree C causes lower evaporation fuel loss, however the evaporation loss increases with increase in temperature to 40 degree C. The highest evaporative fuel loss from 80 mL beaker was observed with 45 degree C for the beaker of capacity 100 mL.

Figure 7 compares the fuel losses from the beaker of capacity 200 mL ai different temperatures such as 35, 40 and 45 degree C. From this figure, it is observed that the evaporation loss of petrol from the beaker increases with time and this trend is similar to figure 5. Since the petrol is volatile fuel, the evaporation loss increases with increase in time. Also, the evaporation loss increases with increase in temperature of the petrol. The petrol temperature of 35 degree C causes lower evaporation fuel loss, however the evaporation loss increases with increase in temperature to 40 degree C. The highest evaporative fuel loss from 80 mL beaker was observed with 45 degree C for the beaker of capacity 200 Ml

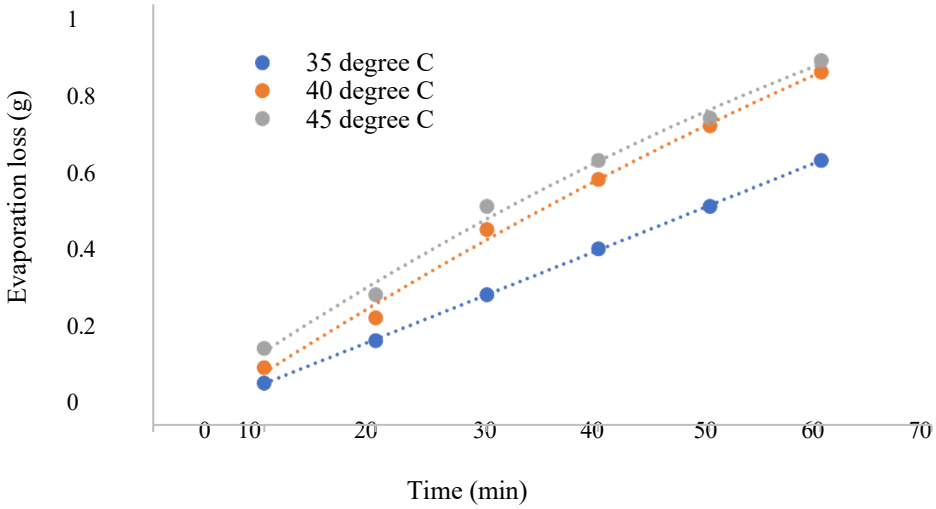

Fig 7. Evaporation loss from 200 mL beaker at different temperatures.

Figure 8 shows the dry bulb temperature (DBT) of air at different timings and it is observed from the figure that DBT of air increases with time and reaches maximum value and then decreases. This is because the solar radiation value increases with time and reaches maximum value at noon and then decreases. The higher ambient temperature may result in heating of the fuel tank which may cause fuel evaporation and fuel loss from the tank.

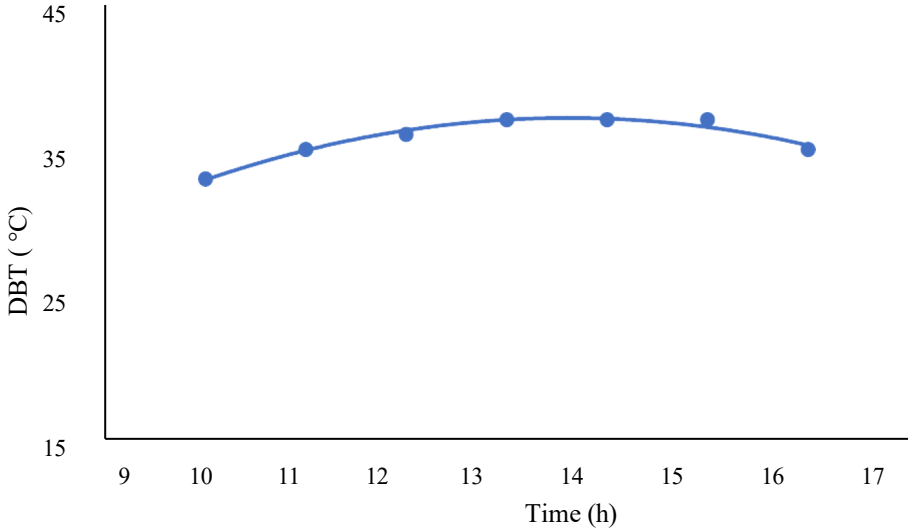

Fig. 8. Dry bulb temperature (DBT) of air at different timings.

6. Conclusion

The evaporation loss from fuel tanks is one of the major sources of fuel loss and the evaporation loss varies with the surface area. In this work, a experimental work was conducted to simulate the fuel tank with different surface area and also different fuel temperature. From the experimental work, it was observed that the fuel evaporation loss increases with time and increase with surface area. The smaller surface is of the petrol causes lesser evaporation loss

as compared to higher surface are of the petrol. It is also observed from the experiments that the fuel evaporation losses increase with increase in fuel temperature. The lowest fuel evaporation loss was observed with 35 degree C and highest was observed with the 45 degree C. The petrol is highly volatile fuel and hence increase in its temperature increases the fuel evaporation loss. The experiments were conducted in summer and the dry bulb temperature of the air was measured. The dry bulb temperature of the air increases with time and reaches maximum at noon and then decreases. Also, the DBT reaches a maximum value of 37 degree C. Hence, it is necessary to take precaution to reduce the fuel losses from the fuel tanks.

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